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A Study on Load Carrying Capacity of Stone Column's Embedded in Compacted Pond Ash

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ABSTRACT

Pond ash deposits possess high compressibility, low bearing capacity so acres of land get wasted. Improvement of load carrying capacity of ash ponds will make them suitable for residential or commercial use. Stone or compacted stone columns is a technique of soil reinforcement that is frequently implemented in soft cohesive soils to increase the bearing capacity of the foundation soil, to reduce the settlement, and to accelerate the consolidation of surrounding saturated soft soil. The stress-strain behavior of the granular column is governed mainly by the lateral confining pressure mobilized in the native soft soil to restrain bulging collapse of the granular column. Several works have been done relating to study the effectiveness of stone column on cohesive material, along with the effect of encasement and without encasement over the stone column. However no studies have been made to explore the effectiveness of stone columns in pond ash deposits. This study relates to there in for cement of pond ash with stone column and possibility of utilizing abandoned ash pond sites for residential or commercial use. The purpose of this work is to assess the suitability of reinforcing technique by stone columns to improve the load carrying capacity of pond ash deposits through several laboratory model tests. This objective is achieved in two parts. In the first stage the characterization of pond ash is made along with the evaluation of the mechanical properties like compaction characteristics under different loading conditions, evaluation of shear strength parameters using Direct Shear Test, Unconfined compression test, Triaxial test at different testing conditions. This is done basically to find out the inherent strength of the pond ash compacted to different densities and at different degree of saturation. In the second series of tests the shear parameters of the compacted pond ash samples reinforced with stone columns of varying area ratios and length ratios are evaluated from triaxial compression test. In addition to this stone columns having different are a ratio and length ratios are introduced in compacted pond ash beds and the bearing capacity of the composite system is evaluated through a series of footing loading tests. For this a circular footing of 75mm in diameter is used.

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KEYWORDS: *Pond ash, triaxial, shear test, vibro-float, crushed stone, stone columns, load tests, horizontal reinforcement*

1. RESULT AND DISCUSSION

1.1. Introduction

Fly ash is a by-product of the coal based thermal power plants contains grains of fine sand to silt size which makes acres of land unsuitable for all human purpose. Presently about 2000 acres of land are being covered by the ash pond. In the present work an attempt has been made to stabilize the deposits in ash pond by reinforcing it with stone columns and without stone column. The effect of replacement ratio, length of stone columns on the strength and stress strain behavior of composite columns has been evaluated. Further the effect of confining pressure and molding pressure on the strength of composite columns has also been investigated. Stabilization of these abandoned ash ponds using stone. In present work the

strength change behavior of reinforced pond ash samples with different parameters of stone column are evaluated by confining pressure and unconfined pressure and also test has conducted of pond ash inside the cylindrical tank with different area ratio and length ratio of stone column reinforced to pond ash. Here two set of test series has conducted one is without reinforcing stone column and another with reinforcing of stone column. The detail tests results are presented and discussed in this chapter.

1.2. Testseries-1

1.2.1. Index properties

1.2.1.1. Specific Gravity

Specific gravity is one of the important physical properties needed for the use of coal ashes for geotechnical and other applications. In general, the specific gravity of coal ashes lies around 2.0 but can vary to a large extent (1.6 to 3.1). The variation of specific gravity of the coal ash is the result of a combination of many factors such as gradation, particle shape and chemical composition. The reason for a low specific gravity could either be due to the presence of large number of hollow cenospheres from which the entrapped micro bubbles of air cannot be removed, or the variation in the chemical composition, in particular iron content, or both .The specific gravity of pond ash was determined according to IS: 2720 (Part-III) -1980 guidelines by pycnometer method with water. The average specific gravity value found to be 2.30. The specific gravity of pond ash was found to be lower than that of the conventional earth material.

1.2.1.2. Determination of grainsize

The grain size distribution curve of pond ash is presented in Fig 1.1. The pond ash consists of grains mostly of fine sand to silt size. The coefficient of uniformity and coefficient of curvature of pond ash sample is found to be 6.13 and 2.61 respectively indicating uniform gradation of sample. The grain size distribution of pond ash mostly depends upon the degree of pulverization of coal and the firing temperature in boiling units. This modern plant having more efficient coal pulverizing equipment tends to produce ashes of finer texture than those from older stations. As the present pond ash sample is from the ash pond of R.S.P, the presence of sediment foreign particles are also expected to present in it. Atterberg Limits was not possible to find out the liquid limit and plastic limit of pond ash indicating that pond ash is non-plastic in nature.

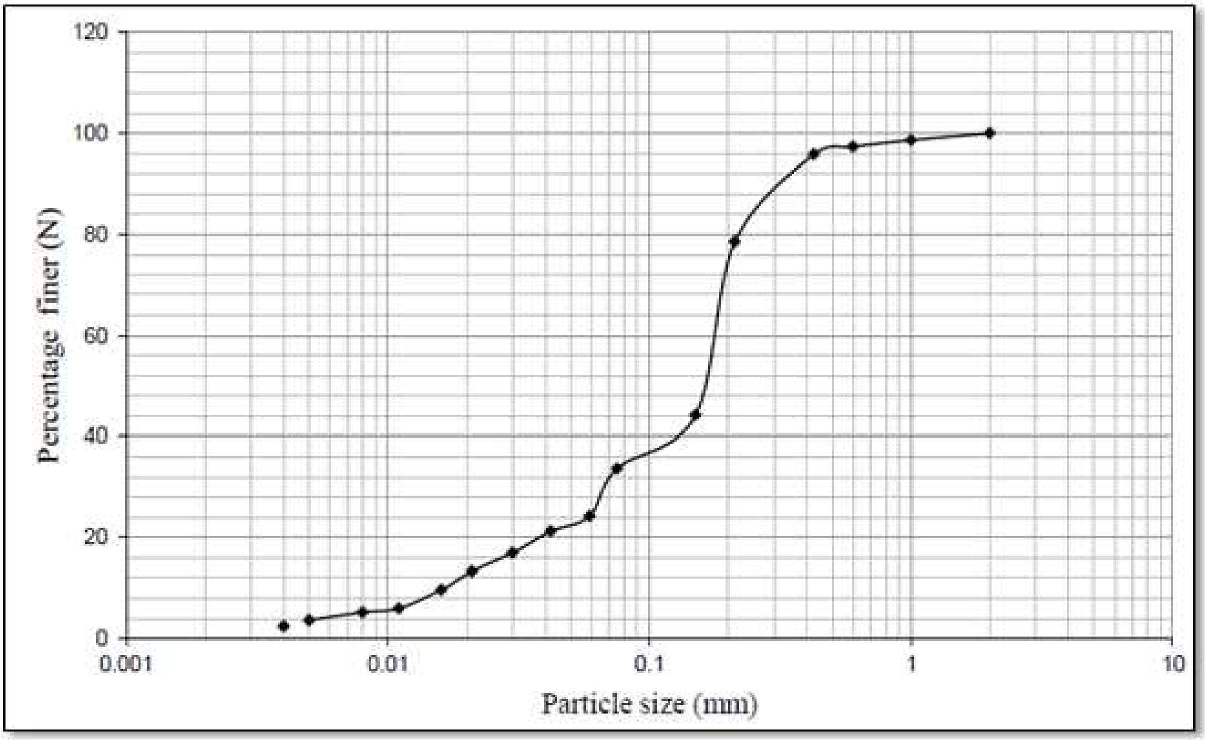

Fig. 1.1: Grain size distribution curve

1.2.2. Engineering properties

1.2.2.1. Compaction Characteristics

The compaction characteristics of pond ash with different compaction energies have been studied by varying the compaction energies 119, 357, 595, 1604 and 2674Kj/m³ of compacted volume. The OMC and MDD of pond ash samples corresponding to these compactive efforts have been evaluated and presented in Table. Relationship between dry density and moisture content of pond ash at different compaction energies have been shown in Fig. It is seen that as the compactive energy increases the MDD increases and the water required to achieve this density is reduced. A continuous increase in the value of MDD is observed with the compactive energy (Fig.4.3). Plot

between OMC and compactive energy shows that initially the OMC decreases rapidly with compactive effort and then the rate of decrease is not that prominent .The MDD of specimens is found to change from 0.984 to 1.23 gm/cm³ with change in compaction energy from 119 to 2674kJ/m3 whereas the OMC is found to decrease from 43.23 to 31.7%. This shows that the compacted density of pond ash responds very poorly to the compaction energy. This may be attributed to the rounded shape of particles and uniform gradation of the sample. There are several factors such as gradation, carbon content, iron content and fineness, etc., which mainly control the compositional properties of lake ash.

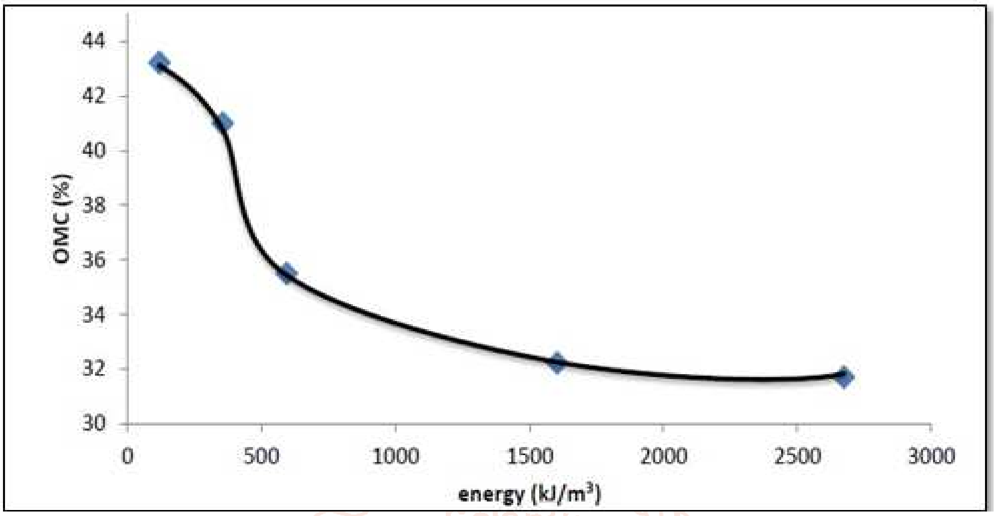

Fig. 1.2: Variation of OMC at different compactive level

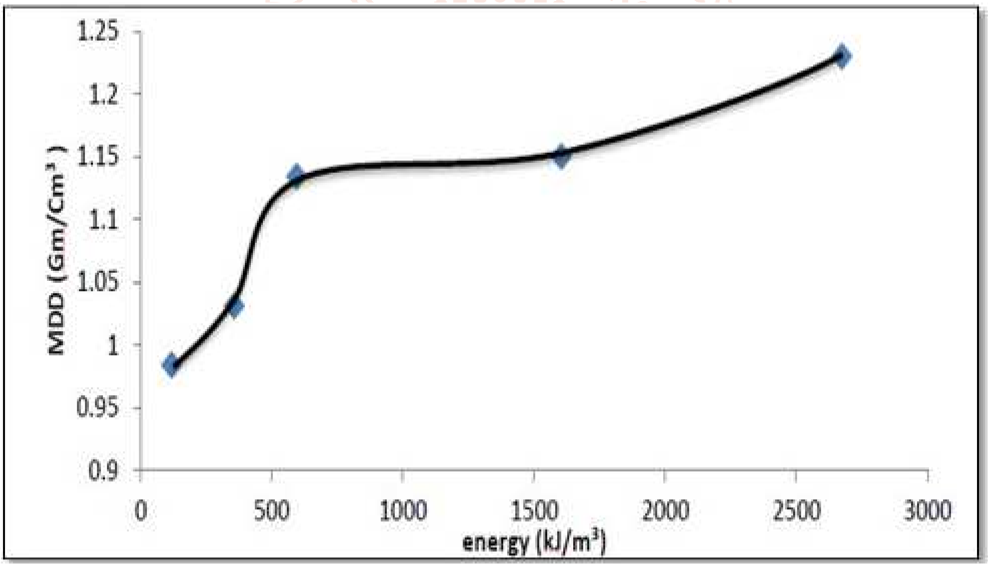

Fig. 1.3: Variation of MDD at different compactive level

1.2.2.2. Effect of saturation on shear parameter

It was found that from direct shear test as the increase of compaction energy the dry density, angle of internal friction also increasing gradually. However the OMC decreases drastically with increase of compaction energy. When the same sample was conducted on direct shear test at saturation same thing has happen as OMC of respective compaction energy and dry density, angle of internal friction also increasing gradually. However the OMC decreases drastically with increase of compaction energy. From the both case at OMC and saturation which result has got at saturation dry density and angle of internal friction is less than OMC result.

Cohesion value of pond ash has increased due to addition of water and compaction energy, due to compaction energy the particle get come closer, the pond ash has some surface activity due to which cohesion value has increased. On the case of saturation the particle has lose its strength of surface activity and cohesion value has decreased as compare to OMC. Angle of internal friction basically depends upon compaction energy it will show maximum at OMC, due to the maximum compaction energy on the case of saturation angle of internal friction has decreased due to water particle will behave as a lubricate effect on the surface of ash pond particle.

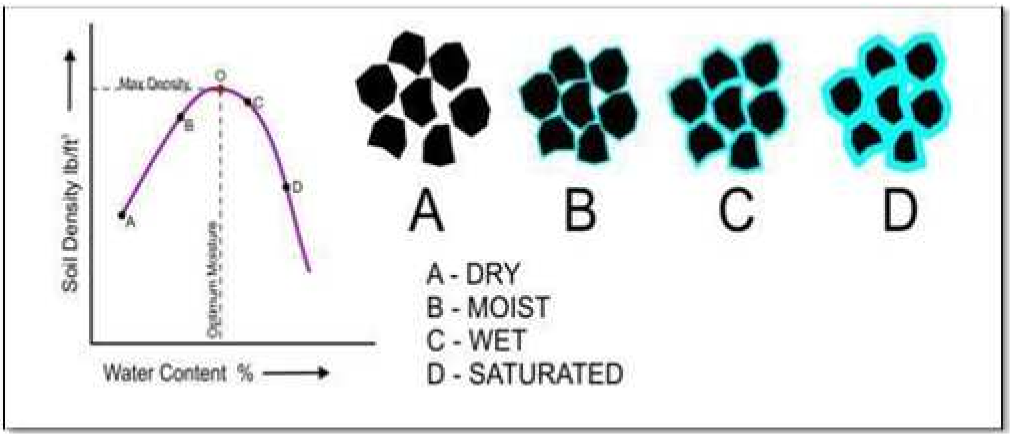

Fig. 1.4: Absorbed and adsorbed water in clay-water systems

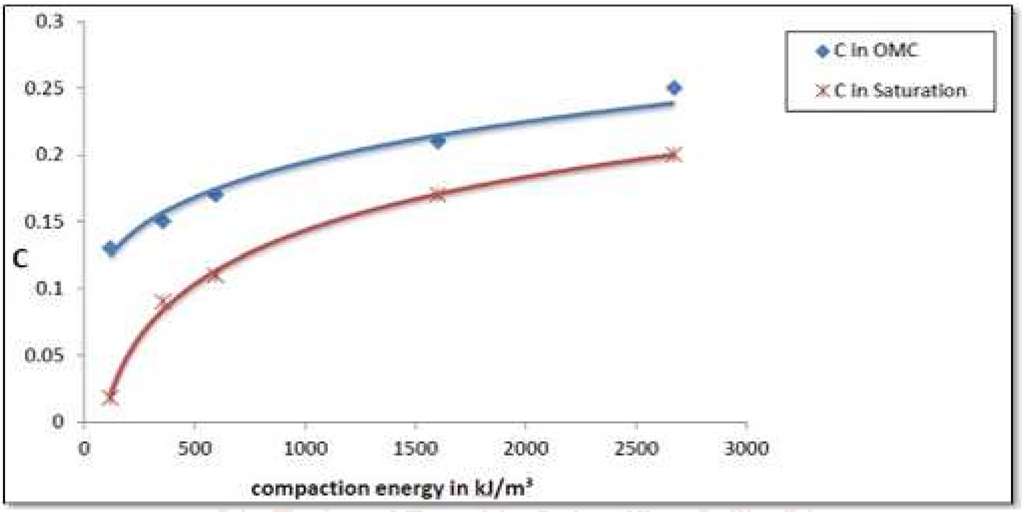

Fig. 1.5: Variation of unit cohesion at OMC and saturation under different compactive level

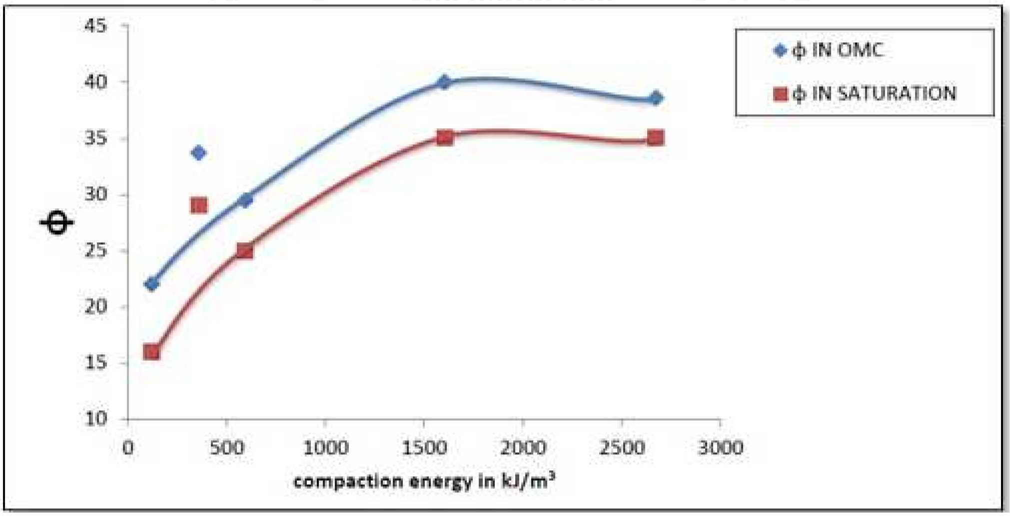

Fig 1.6: Variation of frictional angle at OMC and saturation under different compactive level

1.2.2.3. Determination of Unconfined Compressive Strength
1.2.2.3.1. Effect of Compaction Energy at OMC

Unconfined compressive strength tests were carried out on untreated pond ash specimens compacted to their corresponding MDD at OMC with compactive effort varying as 119, 357, 595, 1604 and 2674Kj/m³. The stress-strain relationships of compacted pond ash were presented in Fig-4.9 Form these plots it is observed that the failure stress as well as initial stiffness of samples, compacted with greater compaction energy, are higher than the samples compacted with lower compaction energy. The immediate compressive strength of pond ash is 19.587 kPa at compaction energy of 119 kJ/m³ which increase to 66.758 kPa at compaction energy of 2674 kJ/m³.However in general the failure strains are found to be lower for samples compacted with higher energies. The failure strains vary from a value of 2.25 to 2.75%, indicating brittle failures in the specimens at sample prepared on higher density shown in Fig- and showing bulging failure under lower density sample shown in Fig. The increase in unconfined strength and initial stiffness of specimens with increased compactive effort is

attributed to close packing of particles, resulting in increased interlocking between particles. A closer packing is also responsible in increasing the cohesion component in the sample.

Fig. 1.7: Bulging failure of compacted pond ash

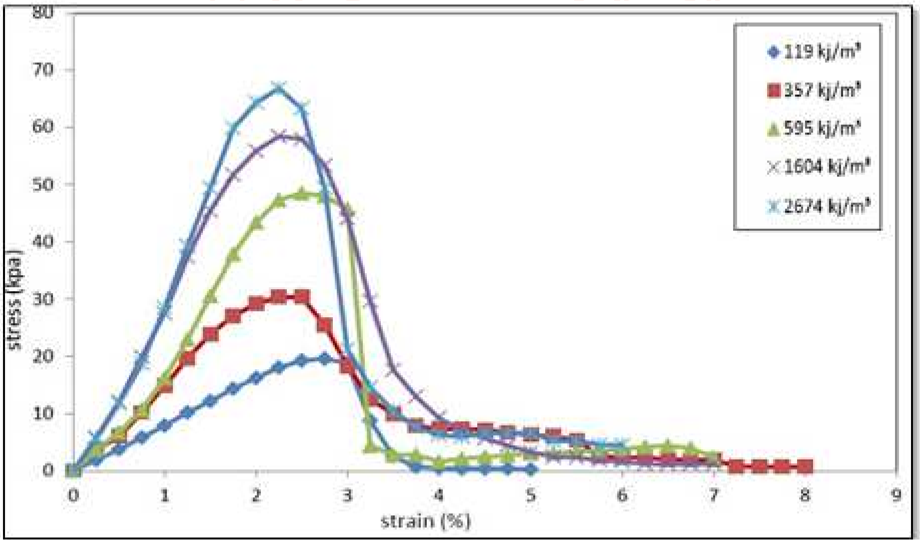

Fig. 1.8: Variation of failure stress-strain in different compactive energy

1.2.2.3.2. Effect of Compaction Energy at saturation

Unconfined compressive strength tests were carried out at saturation on untreated pond ash specimens compacted to their corresponding MDD at OMC with compactive effort varying as 119, 357, 595, 1604 and 2674Kj/m³ then the sample were covered with wax to saturate the sample. The samples were keeping for 30 minute for proper saturation. The stress-strain relationships of compacted saturated pond ash were presented in Fig. These plots show that the failure stress as well as the initial stiffness, the samples compacted with higher compaction energy are higher than the samples compacted with lower compaction energy. The instantaneous compressive strength of lake ash is 8.142 kPa at a compaction energy of 119 kJ/m³ which increases to 38.45 kPa at a compaction energy of 2674 kJ/m³. However the failure stress is generally found to be lower for specimens compacted with higher energy. The failure strains vary from a value of 2.5 to 3%, indicating brittle failures on the both specimens at sample prepared on higher density and lower density sample. Due to the saturation of the sample interlocking between pond ash particle and the void space has filled with small size pond ash particle with some quantity of water and it was proper dense as compare to sample prepare at OMC. So that the stress at saturation is higher as compare to OMC. The increase in unconfined strength and initial stiffness of specimens with increased compactive effort is attributed to the closer packing of particles, resulting in the increased interlocking among particles. A closer packing is also responsible in increasing the cohesion component in the sample.

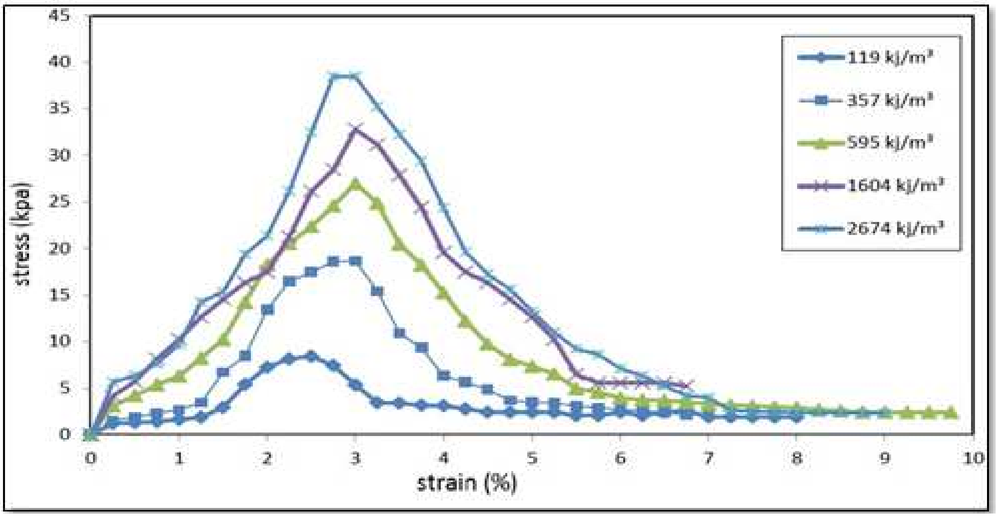

Fig. 1.9: Variation of failure stress-strain in different compactive energy

1.2.2.4. Determination of confined Compressive Strength of pond ash by Traiaxialtest

Triaxial tests were carried out on untreated pond ash specimens compacted to their corresponding MDD at OMC with compactive effort varying as 119, 357, 595, 1604 and 2674Kj/m³. That sample were prepared in dimension of 50mm(dia)x100mm(height) on five respective density of their corresponding compaction energy, on each density to study the effect of confining pressure there were given three confinement pressure was applied as 1,2,3Kg/cm² .The relation between strain and stress was plotted in Fig. From these plot it is observed that under all the confining pressure to their respective compaction energy, the stress value was increasing with the increase of confining pressure from 1kg/cm2 to 3kg/cm2 due to the confinement. The stress value was increased from 3.05kg/cm2 to 8.15 kg/cm2 to their respective increase of confining pressure from 1kg/cm2 to 3kg/cm2 in compactive energy 2674kJ/m³. The stress value was increased from 2.63kg/cm2 to 7.17 kg/cm2 to their respective increase of confining pressure from 1kg/cm2 to 3kg/cm2 in compactive energy 1604kJ/m³. The stress value was increased from 2.02kg/cm2 to 5.94 kg/cm2 to their respective increase of confining pressure from 1kg/cm2 to 3kg/cm2 in compactive energy 595kJ/m³. The stress value was increased from 2.02kg/cm2 to 5.87 kg/cm2 to their respective increase of confining pressure from 1kg/cm2 to 3kg/cm2 in compactive energy 357kJ/m³. The stress value was increased from 1.67kg/cm2 to 4.7 kg/cm2 to their respective increase of confining pressure from 1kg/cm2 to 3kg/cm2 in compactive energy 119kJ/m³. The failure stress of 1kg/cm2 not sufficient to make the sample failure at 3kg/cm2, due to the confinement and sample prepared at higher compactive effort attributed to the closer packing of particles, resulting in the increased interlocking among particles. A closer packing is also responsible in increasing the cohesion component and angle of internal friction in the sample.so that the unit cohesion was increased from 0.106 kg/cm2 to 0.239 kg/cm2 and angle of internal friction was increased from 19.870 to 37.40.

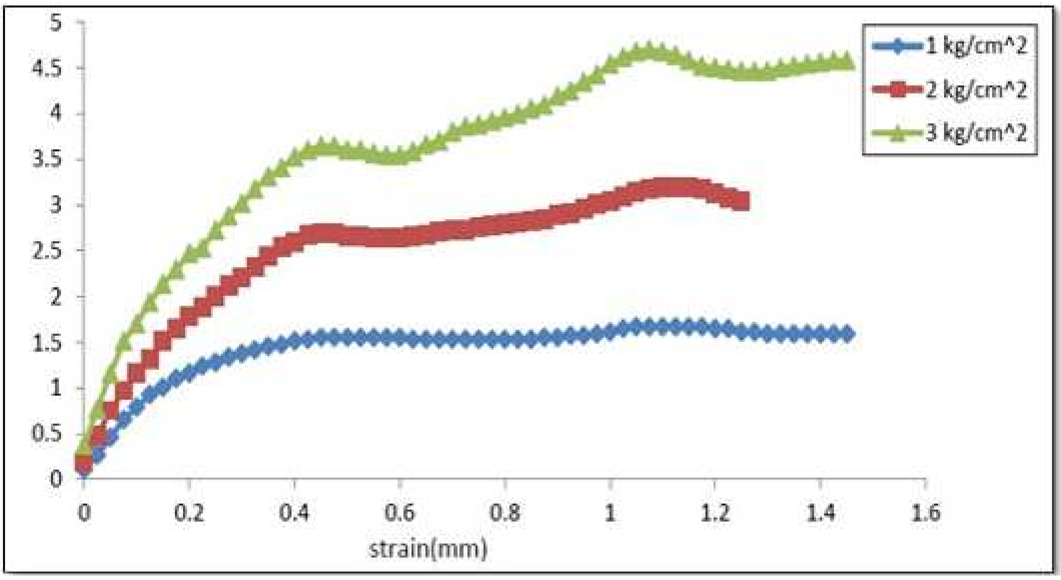

Fig. 1.10: Sample prepared on compaction energy 119 KJ/m³

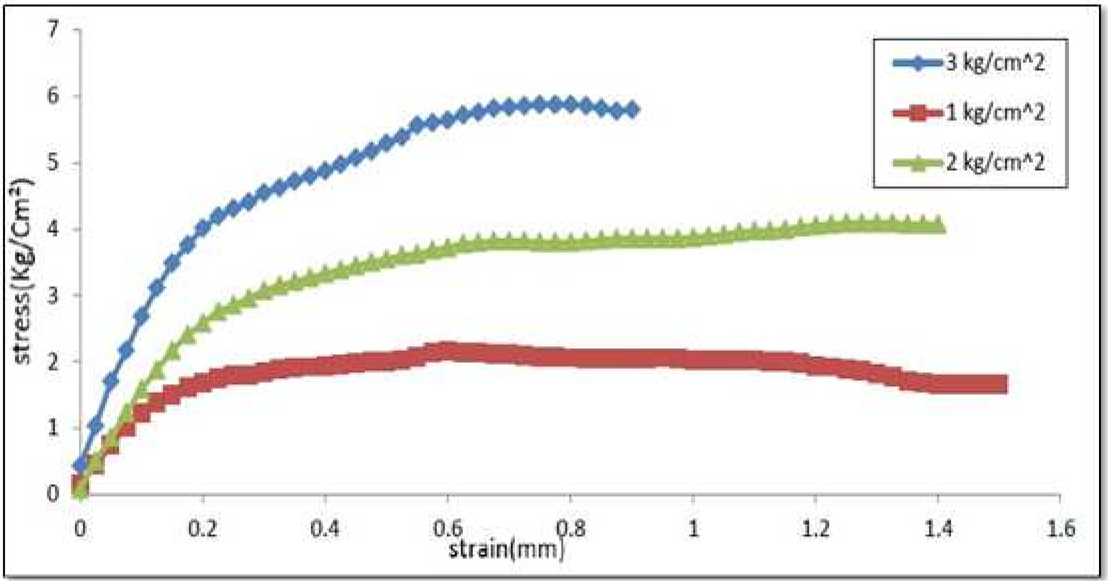

Fig. 1.11: Sample prepared on compaction energy 357 KJ/m³

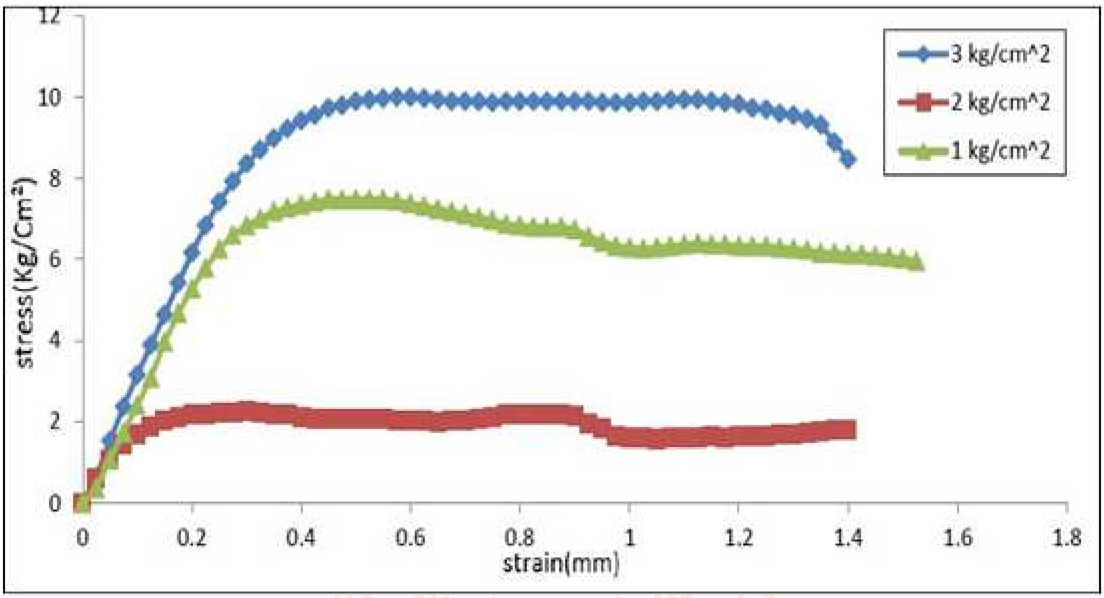

Fig. 1.12: Sample prepared on compaction energy 595 KJ/M³

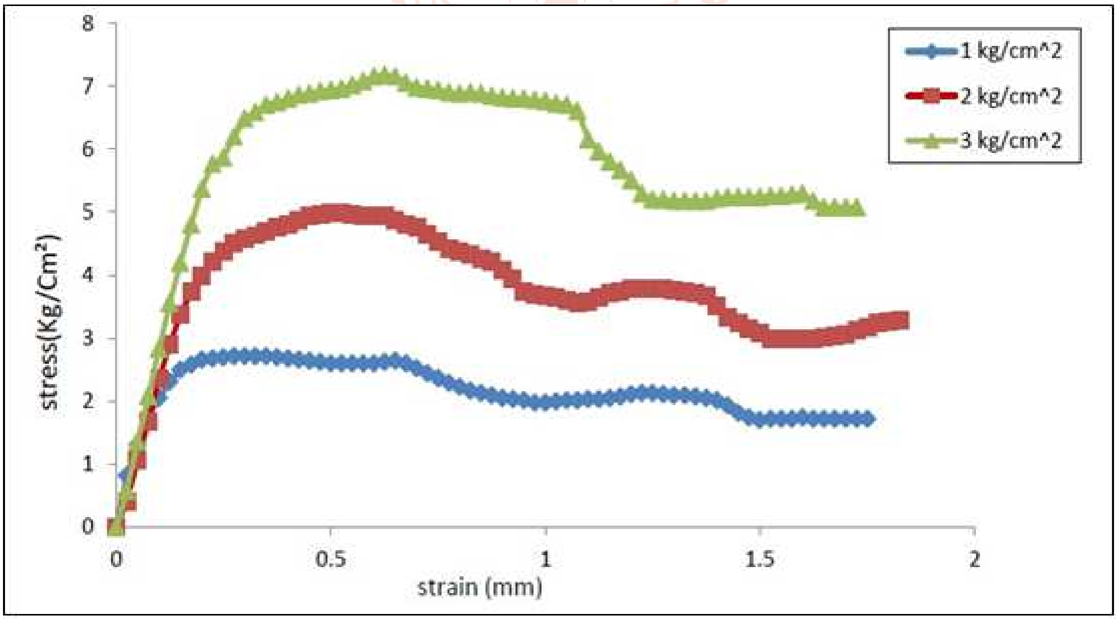

Fig. 1.13: Sample prepared on compaction energy 1604 KJ/M³

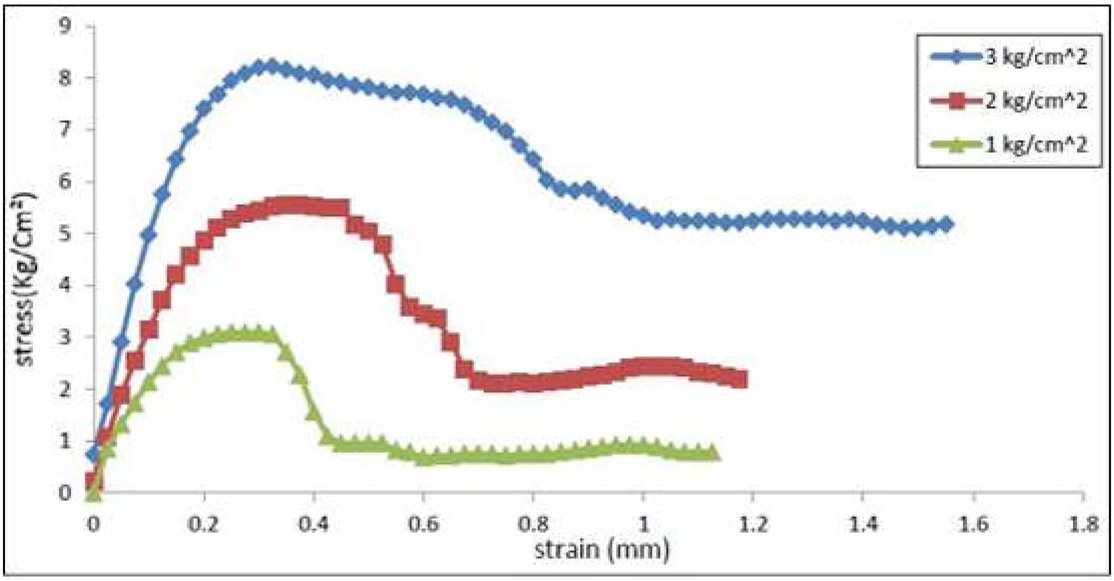

Fig. 1.14: Sample prepared on compaction energy 2674 KJ/M³

1.3. Test series-2

1.3.1. Determination of Unconfined Compressive Strength of pond ash reinforced with stone column

Experimental work was done on the reinforced pond ash by stone column to study the behavior under varying radius of stone column to maintain the area ratio of 10%, 20%, 30% and 40% and along with to study the effect of length ratio on pond ash by varying the length of stone column to provide the length ratio of 0.25Lr, 0.50 Lr, 0.75 Lr, and 1.0 Lr. The stress strain response of reinforced stone column under different condition has study briefly here and the failure pattern of reinforced pond ash has shown in Fig. It is found that reinforced of pond ash by 10% area ratio and by varying its length ratio it has observed that the sequence of stress were as full length stone column Lr wasshowingmaximumstressthen0.75Lrlengthstonecolumnthen0.5Lrandthen 0.25 Lr length stone columns then without reinforced stone column. Stress values were increasing by increasing the length ratio of stone column. The results were shown inFig.

At 20% area ratio stone column with the varying in length ratio by 1Lr,0.75Lr,0.5Lr and 0.25Lr the sequence of stress were as 0.75 Lr was showing maximum stress then 0.5Lr length stone column then without reinforced stone column then 0. 25Lr and then 1 Lr length stone column. The results were shown inFig.

At 30% area ratio stone column with the varying in length ratio by 1Lr,0.75Lr,0.5Lr and 0.25Lr the sequence of stress were as 0.25 Lr was showing maximum stress then without reinforced stone column then 0.5Lr length stone column then 0. 75Lr and then 1 Lr length stone column. The results were shown inFig.

At 40% area ratio stone column with the varying in length ratio by 1Lr,0.75Lr,0.5Lr and 0.25Lr the sequence of stress were as without reinforced stone column then was showing maximum stress then 0.25 Lr length stone column then 0.5Lr length stone column then 0. 75Lr and then 1 Lr length stone column. The results were shown in Fig.

From the above experimental analysis it show that as increasing of area ratio of reinforced pond ash the stress value has decreased with the decreased of strain. At area ratio 10% it has observed that stress value was increasing by increase order of length ratio of stone column whereas at 40% area ratio it was showing reverse. It was due to adequate amount of confining pressure was not sufficient to keep stable sample prepare at 40% area ratio. At 20% and 30% area ratio there is some variation on sequence of stress by the sequence of length ratio.

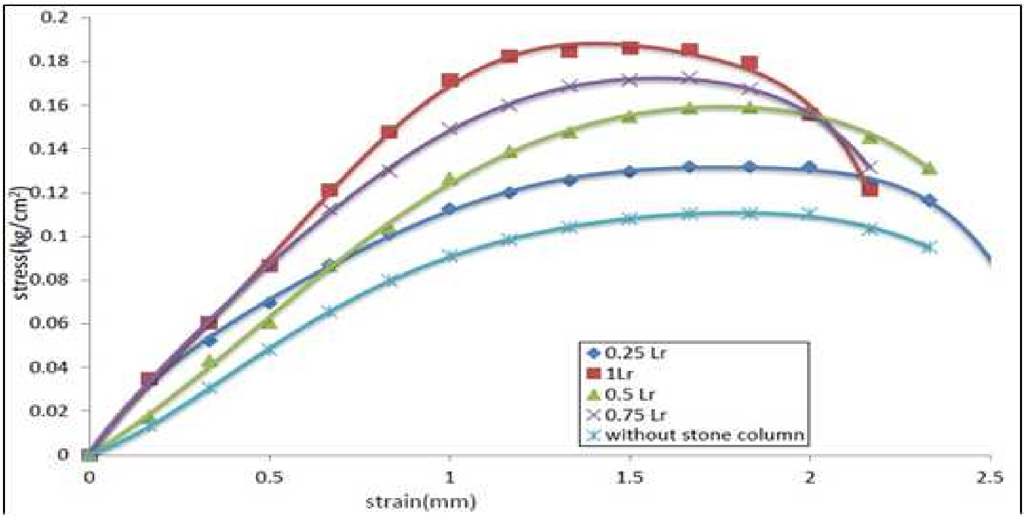

Fig. 1.15: Pond ash reinforced with 2.2cm DIA stone column

1.3.2. Determination of Triaxial test of pond ash reinforced with stone column Triaxial tests were carried out on untreated pond ash specimens compacted to their corresponding MDD at OMC with compactive effort of 94kJ/m3.Here the test was conducted to study the response of pond ash by varying area ratio along with the effect of of their corresponding length ratio .That sample were prepared in dimension of 75mm(dia)x150mm(height) respective density of their corresponding compaction energy, on each density to study the effect of confining pressure there were given three confinement pressure was applied as 1,2,3Kg/cm² .The relation between strain and stress was plotted in Fig-4.23,4.24,4.25,4.26,4.27,4.28,4.29 and 4.30. From these table and graph it has observed that under the confining pressure of 3Kg/cm² in 10% area ratio the stress value was increased from 9.41Kg/cm² to 10.89Kg/cm² by the increase of length ratio from 0.25 to 1 ,when compare with without reinforced stone column, without reinforced stone column shown maximum stress from 0.25 reinforced length ratio. Under the confining pressure of 2Kg/cm² in 10% area ratio the stress value was increased from 6.12Kg/cm² to 7.86Kg/cm² by the increase of length ratio from 0.25 to 1 , when compare with without reinforced stone column, without reinforced stone column shown maximum stress from 0.25 reinforced length ratio. Under the confining pressure of 1Kg/cm² in 10% area ratio the stress value was increased from 3.48Kg/cm² to 4.08Kg/cm² by the increase of length ratio from 0.25 to 1 , when compare with without reinforced stone column, without reinforced stone column shown maximum stress from 0. 5 reinforced length ratio.

Under the confining pressure of 3Kg/cm² in 20% area ratio the stress value was increased from 10.25Kg/cm² to 12.87Kg/cm² by the increase of length ratio from 0.25 to 1 , when compare with without reinforced stone column, without reinforced stone column shown low stress from other reinforced stone columns. Under the confining pressure of 2Kg/cm² in 20% area ratio the stress value was increased from 6.94Kg/cm² to 9.149Kg/cm² by the increase of length ratio from 0.25 to 1 , when compare with without reinforced stone column, without reinforced stone column shown low stress from other reinforced stone column. Under the confining pressure of 1Kg/cm² in 20% area ratio the stress value was increased from 3.89Kg/cm² to 4.85Kg/cm² by the increase of length ratio from 0.25 to 1 , when compare with without reinforced stone column, without reinforced stone column shown low stress from other reinforced stone column.

Under the confining pressure of 3Kg/cm² in 30% area ratio the stress value was increased from 11.85Kg/cm² to 14.21Kg/cm² by the increase of length ratio from 0.25 to 1 , when compare with without reinforced stone column, without reinforced stone column shown low stress from other reinforced stone columns. Under the confining pressure of 2Kg/cm² in 30% area ratio the stress value was increased from 7.89Kg/cm² to 10.24Kg/cm² by the increase of length ratio from 0.25 to 1 , when compare with without reinforced stone column, without reinforced stone column shown low stress from other reinforced stone columns. Under the confining pressure of 1Kg/cm² in 30% area ratio the stress value was increased from 4.24Kg/cm² to 5.68Kg/cm² by the increase of length ratio from 0.25 to 1 , when compare with without reinforced stone column, without reinforced stone column shown low stress from other reinforced stone column.

Along with when compare the area ratio of their respected length ratio with other confining pressure the stress value was increased by increase of confining pressure. So here due to full length of stone column and confining pressure the stone column show more effective as compare to other because of the closer packing of particles, resulting in the increased interlocking among particles. A closer packing is also responsible in increasing the cohesion component and angle of internal friction in the sample.

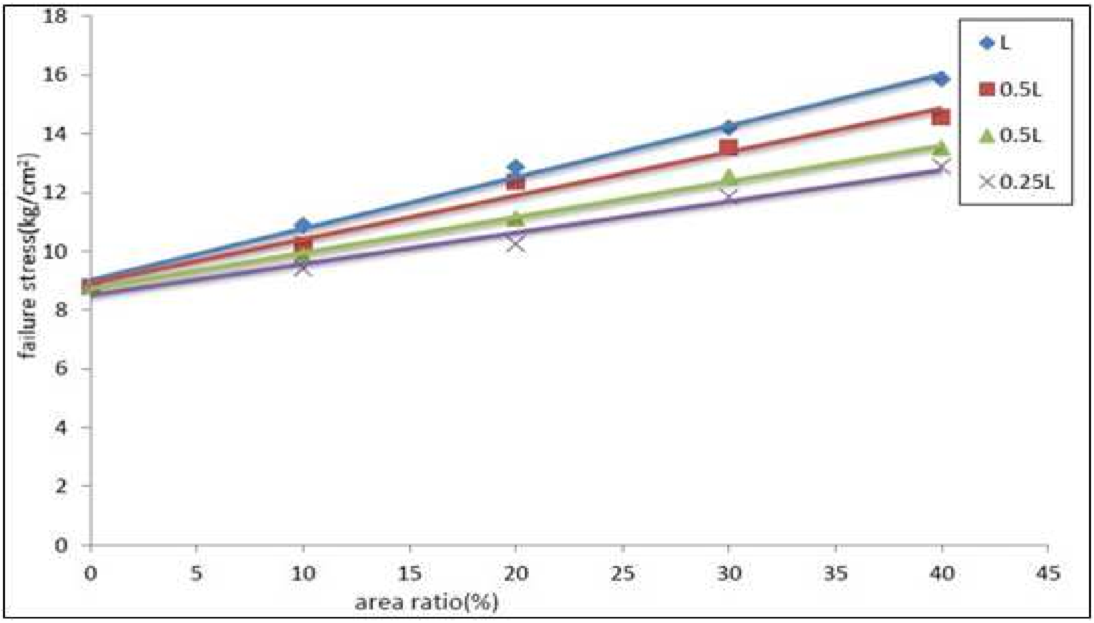

Fig. 1.16: Variation of failure stress with area ratio at 3kg/cm^2 confinement

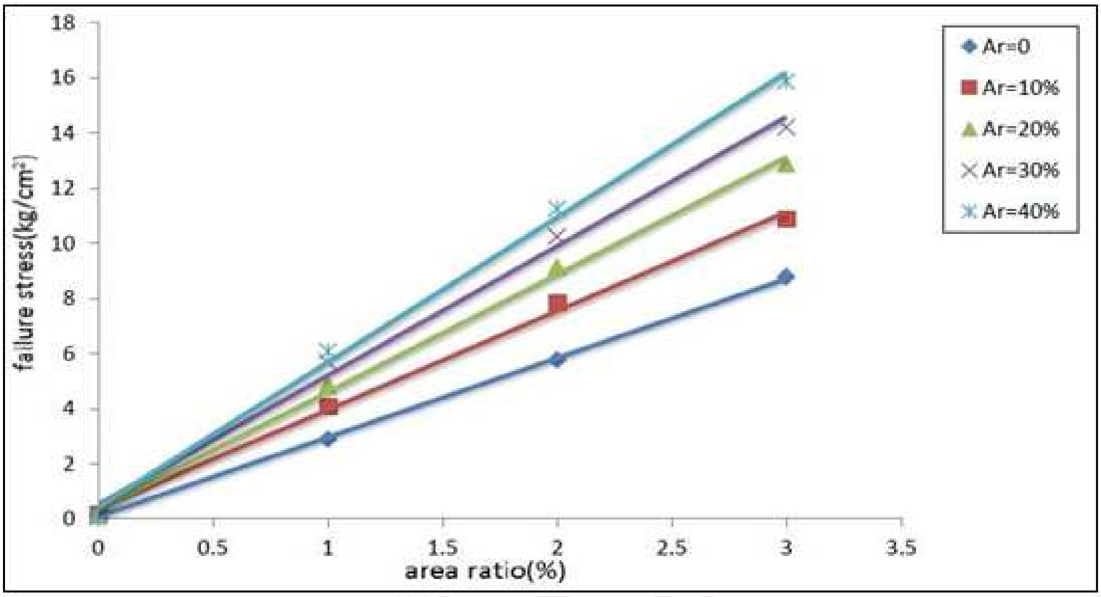

Fig. 1.17: Variation of failure stress in full length reinforced pond ash in different confinement pressure

1.3.3. Bearing capacity of stone columns

1.3.3.1. Load settlement behavior

Footing load tests were carried out on untreated pond ash specimens compacted to their corresponding MDD and OMC .This test was carried out to study the load settlement behavior of pond ash reinforced with stone column in different length ratio of their respected area ratio and the test result and behavior has plot in Fig. From these graph it is observing that the by increase of length ratio from 0.25 to 1the failure stress of varying area ratio 10,20,30,40% is 2.844 to 4.124 kg/cm2,3.26 to 4.868 kg/cm2,4.133 to 6.234 kg/cm2 and 4.767 to 7.841 kg/cm2 respectively. From the graph it can be concluded that for each length ratio the failure stress increases linearly with the area ratio. With the decrease in the length ratio, the failure strain is observed to be increasing. This is due to the fact that, for the case of higher length ratio the stone column- having a higher angle of friction and higher density- leads to a lower strain. For the case of low length ratio, the particles of the stone column and the pond ash settle on application of the load. However, since pond ash forms a major portion of the specimen, the strain caused is higher than for the larger length ratios. It shows higher stress for higher area ratios. Similarly higher stresses for a particular area ratio were observed for higher length ratios. Because of the higher angle of internal friction it has, stone column plays a major part in increasing the strength of pondash.

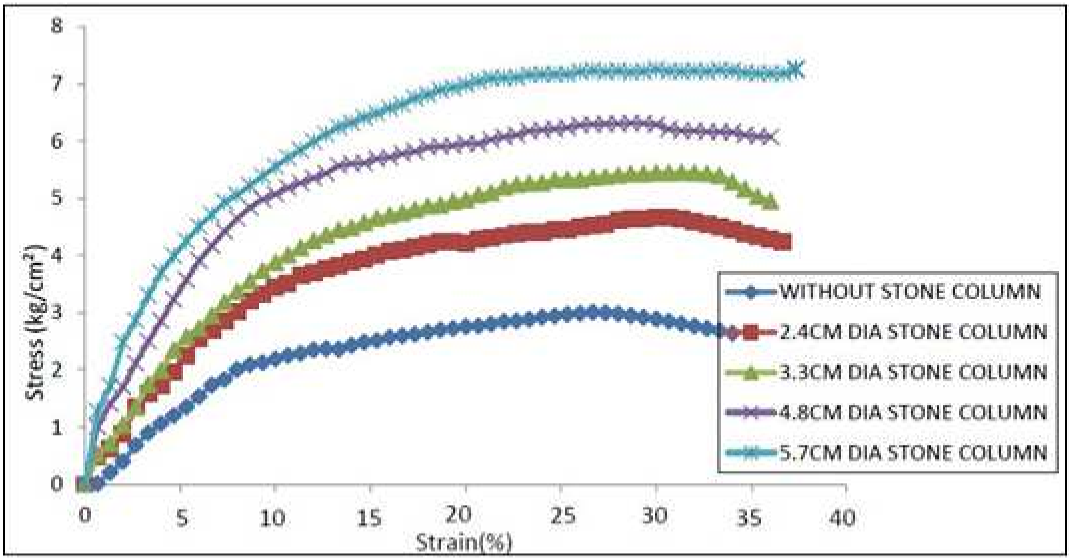

Fig. 1.18: Variation of failure stress and settlement in full length reinforced pond

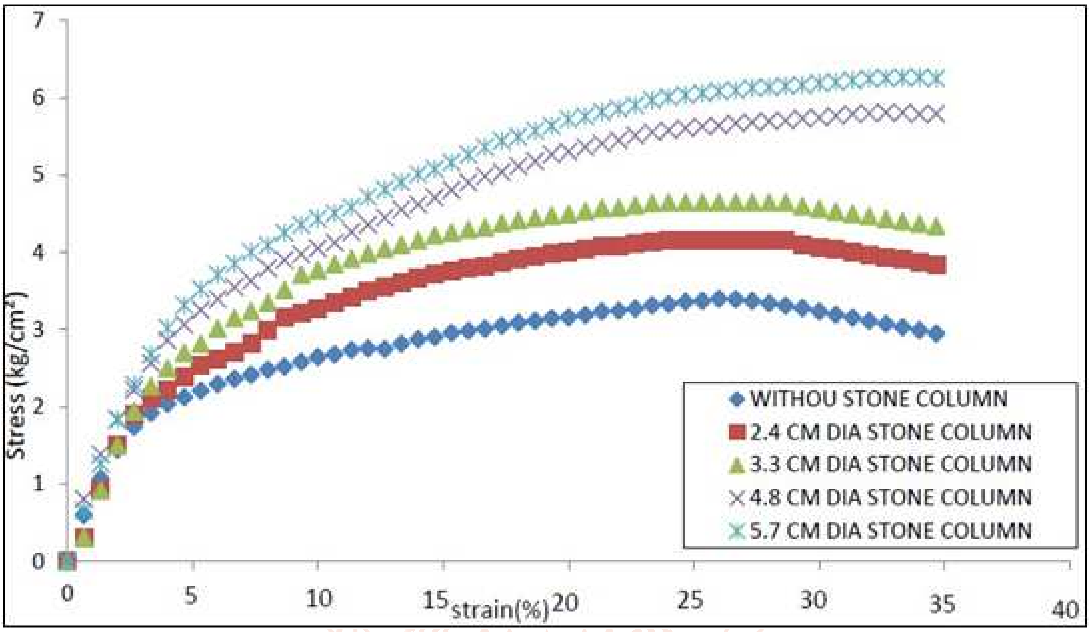

Fig. 1.19: Variation of failure stress and settlement in 0.75 length reinforced pond ash

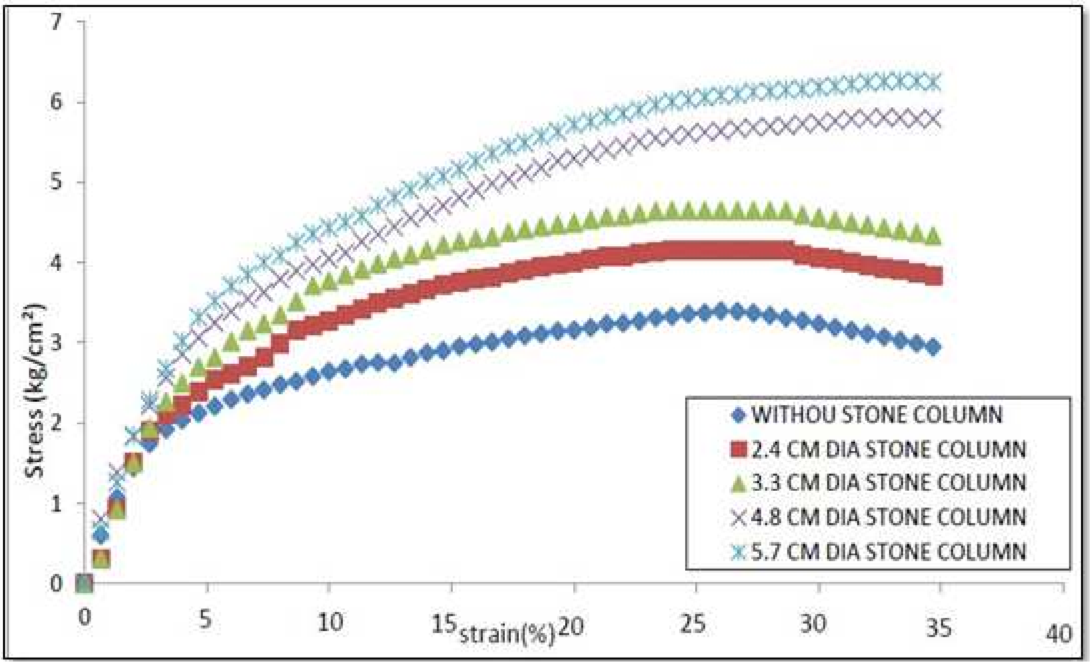

Fig. 1.20: Variation of failure stress and settlement in 0.5 length reinforced pond ash

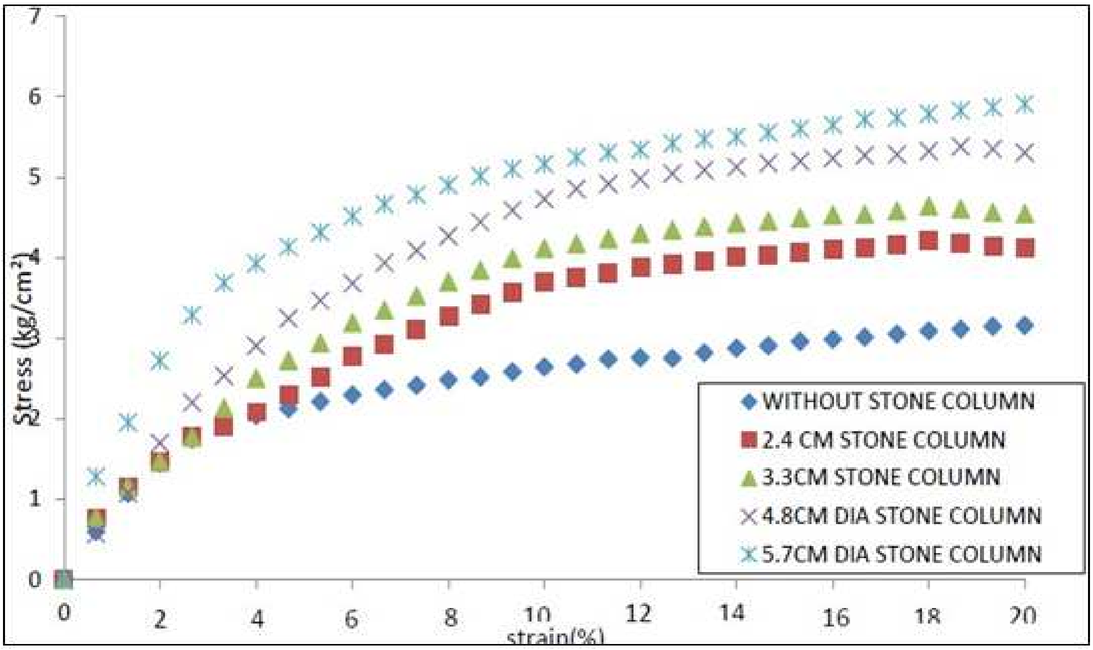

Fig. 1.21: Variation of failure stress and settlement in 0.25 length reinforced pond ash

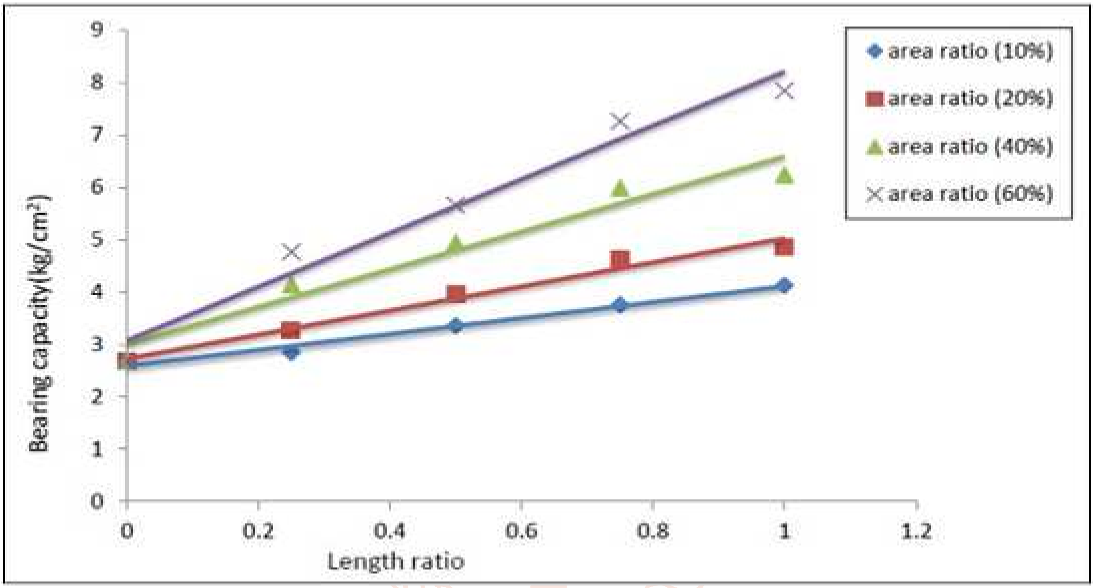

Fig. 1.22 Variation of bearing capacity with length ratio

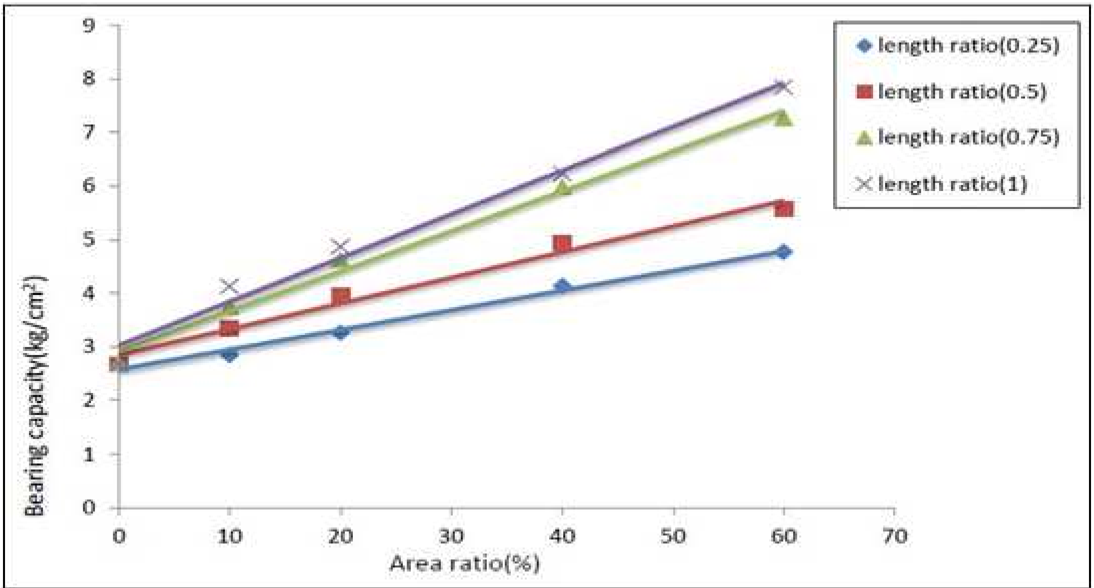

Fig. 1.23: Variation of bearing capacity with area ratio

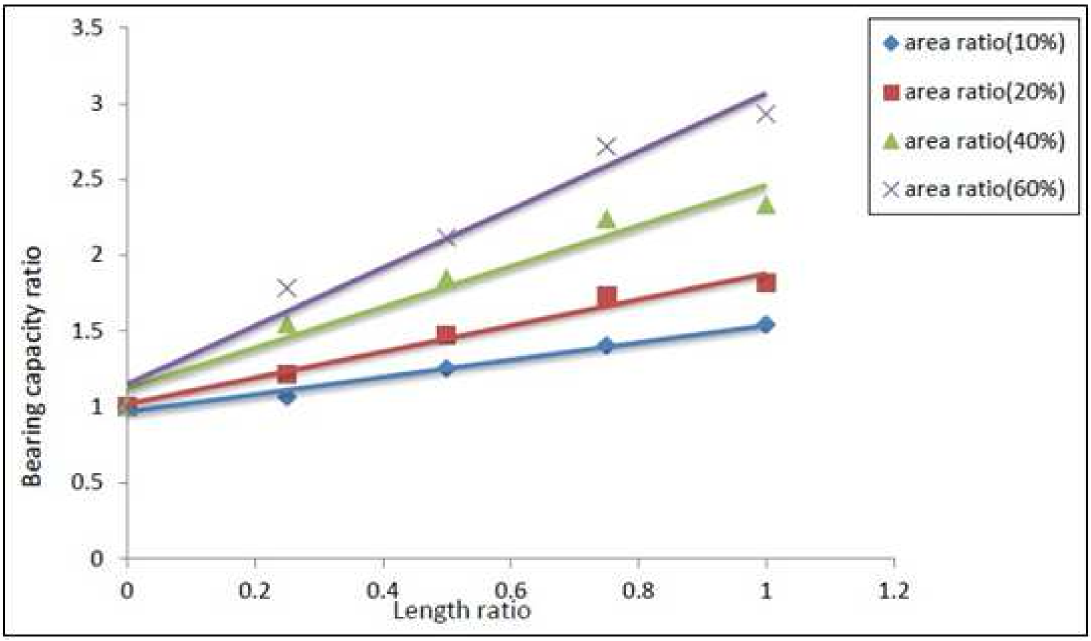

Fig. 1.24 Variation of bearing capacity ratio with length ratio

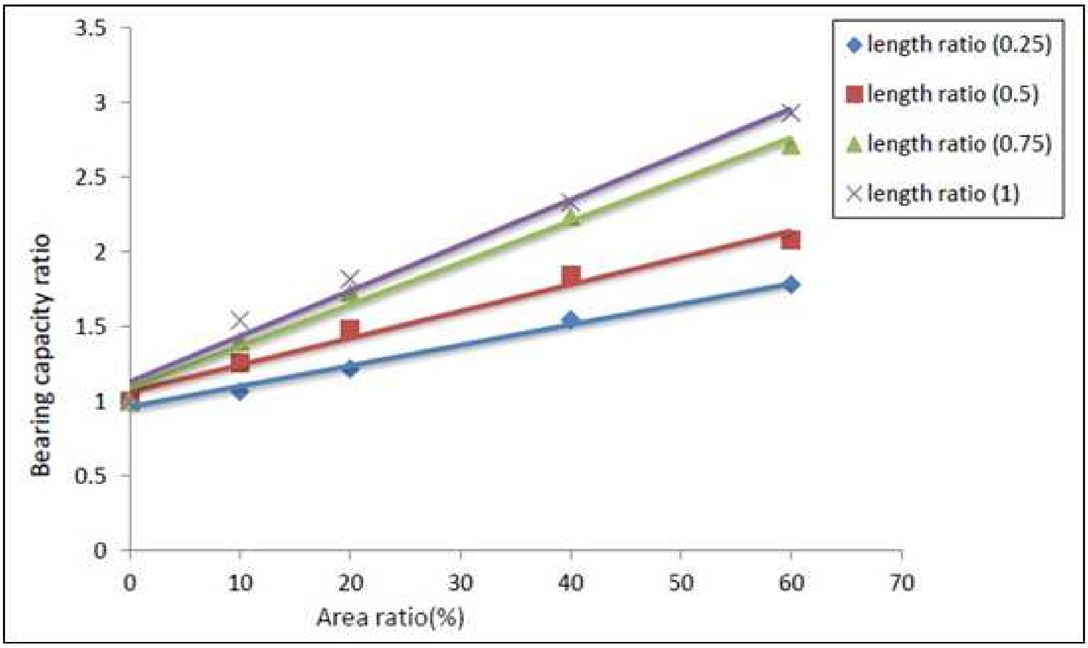

Fig. 1.25 Variation of bearing capacity ratio with area ratio

It is observe that with the increase of length ratio to their respected area ratio bearing capacity increases linearly. It shows that with the increase of stone column diameter and reinforcing length due to high compacted density the frictional angle increases linearly in result bearing capacity also increases linearly. The stone column diameter and length plays a major part in increasing the bearing capacity of stone column.

There has mention bearing capacity ratio which is the ratio of bearing capacity of reinforced pond ash to bearing capacity of without reinforced stone column. From that fig it is observe that as the increase of length ratio of the respected area ratio bearing capacity also increases but at 0.75 length ratio reinforced pond ash has more effective as compare to other if considering the use of materials. At full length reinforced pond ash shows bearing capacity is closer to 0.75 length ratio reinforced pond ash but requirement of material is more.

2. CONCLUSION AND FUTURE SCOPE

2.1. Conclusion

Lake ash consists mostly of fine sand to silt size particles and has a uniform particle gradation. The percentage of pond ash passing 75µ sieve was found to be 18.84%. Coefficient of uniformity (Cu) and coefficient of curvature (Cc) for fly ash were found to be 6.13 and 2.61 respectively, indicating uniform grading of the samples. The specific gravity of the particles is lower than that of conventional earth materials. Condensation energy was found to change from 119kJ/m3 to 2674 kJ/m3 in dry unit weight of solidified samples from 0.984 to 1.23 gm/cm3, while OMC was found to decrease from 43.23 to 31.7%. The low condensation density can be attributed to the spherical shape of the particles, uniform gradation of

the sample and low specific gravity of the constituent particles. A linear relationship is found between compaction energy and raw compressive strength. The UCS value is found to change from 19.587 to 66.758 kPa with compaction energy changing from 119kJ/m3 to 2674kJ/m3, indicating that the increase in strength is not so remarkable. The test results show that a linear relationship exists between the initial tangential modulus and the deformation modulus with the rough compressive strength. At saturation condition UCS value varies from 8.142 to 38.45 kPa, condensation energy varies from 119kJ/m3 to 2674kJ/m3. These values are much lower than those obtained at OMC. This indicates that saturation of lake ash samples results in a sharp reduction in strength.

A close packing is also responsible for increasing the internal friction factor and angle in the specimen. Hence the unit cohesion increased from 0.106 kg/cm2 to 0.239 kg/cm2 and the angle of internal friction increased from 19.870 to 37.40. The UCS tests showed that all area ratios and their length ratios of reinforced stone columns with increased area of reinforced pond ash resulted in a decrease in stress value. At an area ratio of 10% it is found that the value of stress increases with increasing length ratio of the stone column while at an area ratio of 40% it shows the reverse. Sufficient confining pressure was not sufficient to produce a stable sample with a volume of 40%area.

For the case of low length ratio, the particles of the stone column and the pond ash settle on application of the load. However, since pond ash forms a major portion of the specimen, the strain caused is higher than for the larger length ratios. It shows higher stress for higher area ratios. Similarly higher stresses for a particular area ratio were observed for higher length ratios. Because of the higher angle of internal friction it has, stone column plays a major part in increasing the strength of pond ash. For the effective and economic purpose it is observing that the increase of length ratio of the respected area ratio bearing capacity also increases but at 0.75 length ratio reinforced pond ash has more effective as compare to other if considering the use of materials. At full length reinforced pond ash shows bearing capacity is closer to 0.75 length ratio reinforced pond ash but requirement of material is more.

2.2. Scope of future work

- Test should be carried out on group of stone columns loaded simultaneously
- Behavior of jacketed and anchored stone columns be studied
- Liquefaction susceptibility of the system to be studied
- Studies on stone columns with horizontal reinforcement

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